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(54) APPARATUS FOR CONTINUOUS CASTING

(71) We, ALCAN RESEARCH AND DEVELOPMENT LIMITED, a Company incorporated under the laws of Canada, of 1, Place Ville Marie, Montreal, Quebec, Canada, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to continuous casting of metals in the form of strip and in particular it relates to methods and apparatus for casting metals, such as aluminium (including aluminium alloys) and zinc and other metals which melt at a similar or lower temperature, between a pair of moving surfaces, which are constituted by flexible metallic belts.

It has long been apparent that significant economies should be attainable in the production of aluminium strip and sheet if wide thin slab for hot rolling or wide thick strip for cold rolling, could be cast at high rates, and hence at low cost, and with the high surface and sub-surface quality necessary to provide the final rolled product quality when the cast stock is rolled without surface treatment for removal of casting defects.

In operation, existing casting apparatus employing a pair of spaced flexible metallic belts to define a casting zone or mould space do not satisfy these requirements. Although existing apparatus may be operated to give high production rates, the cast stock tends to be of uneven thickness and to have surface imperfections caused by surface exudates of material differing markedly in composition, and hence in properties, from material of the average composition of the cast stock. This is accompanied by sub-surface variations of metallurgical structure which are likewise a source of variation of properties. These surface exudates and sub-surface defects arise from variations of freezing rate between one part of the cast slab or strip surface with respect to other parts. Such variations are believed to arise from the development of gaps between parts of the cooling surface of the casting and the adjacent area of the moving belt surface. Into these gaps, between the belts and the consequently uncooled adjacent casting surface, low melting liquid can exude to form the above mentioned surface exudates. The present invention eliminates these surface and sub-surface defects by a means which also provides a solution to the problem of inconsistency of cross-sectional shape of the cast stock for satisfactory strip shape control in subsequent rolling operations.

It is the principal object of the present invention to provide an apparatus for the continuous casting of metal, such as aluminium, in which the belts move on a precisely controlled path, which is arranged so that the metal cast in the mould space remains in close contact with the belt during the casting operation so that heat maybe removed through the belt in a uniform manner and so that any gaps developed between the belt and the freezing strip are so small as to have no adverse effects on the surface or sub-surface quality of the cast strip or slab.

Many constructions of apparatus have been put forward in which a pair of moving, water-cooled parallel belts are employed for the purpose of defining a mould space, the narrower side edges of which are closed by edge dams. Whilst in the practical application of such apparatus it has been found preferable to employ flexible or articulated side dams which move with the belts, in some early forms of such apparatus a stationary, water-cooled edge dam was employed so that the metal at the sides of the mould

space solidified more rapidly than the metal at the middle with the result that the emerging strip tended to be thicker at the edges than at the middle.

To counteract that difficulty it was proposed in U.S. Patent No. 2,640,235, in an apparatus primarily designed for casting steel, to produce an outward bowing of one or both of the upper and lower belts in the zone in which the molten metal is poured. The distance apart of the belts at the middle of the space is thereafter progressively decreased while the spacing at the edge of the belts is maintained constant. The use of magnetic force to act on the belts during part of their travel through the zone in which they form the boundaries of the mould space was proposed, but this was in conjunction with exceptionally heavy tension in the belts required to ease the bowing of the belts at the critical portion of the casting zone and in fact the effect of such magnets in controlling the path of the belts could only be minimal since the belts are indicated as being spaced from the magnets by non-magnetic spacers of such dimensions as to leave the requisite water passages between the magnet and the belt and it is found experimentally that no substantial magnetic force can be obtained in that way. Moreover, since the centre of the belts is less heavily tensioned than the edges it is to be expected that the centres of the belt would sag away from the spacers. Since the object of that apparatus was primarily to obtain strip of more uniform gauge than previously without imposing pressure on it between the belts, such sagging might be of little importance. By contrast with U.S. Patent No. 2,640,235 the apparatus of the present invention relies on guiding the casting belts in very closely defined paths so as to ensure that at any position in the casting zone the rate of heat removal is substantially equal across the full width of the casting zone and that the longitudinal taper (if any) is substantially constant at all positions across the width to ensure rapid removal of heat at all positions in the casting zone and thus to avoid the formation of exudates.

According to the present invention, there is provided a method for the continuous casting of metal in strip form comprising introducing molten metal in to a mould space defined between a pair of moving heat conducting ferromagnetic belts, extracting heat from said metal by cooling the reverse surfaces of said belts at said mould space, supporting said belts at said mould space by means of spaced belt supports in contact with the reverse surfaces thereof, applying a magnetic force to at least one of said belts by means of a plurality of spaced magnetic belt supports distributed over the area of the mould space to hold said belt against said supports, the magnetic force being related to the spacing between the supports and to the belt thickness to constrain said belt against buckling under the thermal stresses remaining after cooling.

According to a further feature of the invention apparatus for carrying out this method comprises a pair of movable heat conducting ferromagnetic belts defining therebetween said mould space, said apparatus including at each side of said mould space a plurality of spaced belt supports distributed over the area of the mould space and defining the path of a belt in contact therewith, at least one of said belts being held against its supports by magnetic force applied through its said supports and means for cooling the reverse faces of said belts at said mould space, the mutual spacing between said belt supports at each side being less than 50 times the thickness of said belts. For cooling the belt efficiently and uniformly, we prefer the jet cooling system which is described later, since by that means particularly rapid and uniform extraction of heat from the belt may be obtained and thus the temperature rise in the belt and the temperature variation across the belt width are minimised. In consequence the risk of thermal distortion of the belt is minimised. Even with uniform heat extraction across the width, the temperature gradient through the belt produces a thermal stress tending to buckle the belt, but with our very efficient cooling system this stress is held to low levels and is easily counteracted by a relatively small force.

Since some of the alloys which it is desired to cast continuously by the present method contract by several percent during solidification, it is highly desirable to provide means for reducing progressively the spacing between the two opposed faces of the mould space so as to maintain any gap between the belts and the surfaces of the strip at a very low value whilst the metal is passing through the zone in which solidification takes place. The use of fixed magnetic pole pieces acting as belt supports in direct contact with the belt permits any desired profile to be applied very simply to the mould space. In disposing units, of which the pole pieces form part, the mould space may be arranged so as to close progressively in the zone in which the metal undergoes solidification. The amount by which the mould faces must progressively approach each other will vary with the thickness of the strip and in the case of the thinnest strip the variation may be no more than a few thousandths of an

inch. It is possible to provide rotatable elements as belt supports which control the profile of a moving belt to this order of accuracy and such devices are within the scope of the invention but in the preferred form of apparatus the belt is made to slide over stationary pole pieces, because these can be made and maintained to closer dimensional tolerances than rotatable elements. With either type the belt is made to conform closely with its profiled backing by magnetic attraction which provides the force required to pull the belt into intimate contact with its supports.

The heat transfer from the cast slab or strip to the cooling water via an interposed metal belt is characterised by a very large temperature drop at the metal/belt interface, a modest temperature drop through the metal belt, and another modest but larger temperature drop at the belt/water interface. The mean temperature of the metal belt is thus higher than that of the water coolant and it is desirable to minimise this difference in temperature between the belt and the coolant, and particularly to minimise variations of the belt temperature rise at various positions along the length, and more particularly across the width of the belt because this minimises the thermal stresses which might otherwise cause the belt to buckle and leave its intended precisely defined path. Increasing the heat transfer coefficient at the belt/water interface lowers the belt mean temperature for a given rate of heat transfer through the metal/belt interface. Even when the belt is free of an insulating coating at the surface adjacent to molten aluminium we have found it possible to achieve belt/water heat transfer coefficients sufficiently high to keep the mean belt temperature rise to modest levels which are compatible with the need to avoid thermal buckling. We find that the physical dimensions and other characteristics of our jet cooling system are readily compatible with our provision of closely spaced belt path supports. With metal belts of the thicknesses which are consistent with flexibility requirements on the one hand, and dent resistance requirements on the other, we are able to constrain the belts into sliding contact with supports spaced apart by distances which are only of the order 30 to 50 times the belt thickness. This constraint effectively makes the flexible belt extremely resistant to buckling and in combination with out efficient belt cooling system provides a moving heat exchanging membrane which follows its intended path to the precision required to achieve the prime objective of our invention.

In apparatus of this class the belts which define the broad faces of the moulds or casting zone within which a strip or thin slab of metal is cast each constitute a heat exchange surface through which heat from the solidifying metal is transferred to water on the opposite side of the belt. The rate at which sheet or slab of a given thickness may be cast is dependent upon the rate at which heat can be transferred through the belt to the coolant water and it is therefore important that the arrangement for heat transfer from the cast metal to the coolant shall be efficient.

In one well known form of casting apparatus of the present type, each of the belts is supported by end pulleys for drive and tensioning purposes. The length of each belt lying in the casing zone is backed by several rows of thin, spaced discs, each row of discs being mounted on a common spindle. The back of each belt is cooled by means of a rapidly moving sheet of water, the flow of which is only slightly affected by the discs. The discs serve as virtual point supports for the back of the belt, so that substantially the whole of the rear surface of the belt is available for heat transfer from the belt to the coolant.

The flow of coolant lengthwise of the belt is normally established by projecting a sheet of water at a shallow angle of about 10° against the back of the belt by directing jets of water onto an inclined surface extending across the belt between two rows of discs and having an edge in close proximity to the surface of the belt. Each such sheet of coolant is largely removed by a scoop as its velocity decreases and is replaced by a fresh rapidly moving sheet of water, created in the same way, so that in effect the whole rear surface of the belt is covered by a rapidly moving sheet of water.

In the known apparatus, referred to above, it is usual to apply a thermal insulation coating to the surface of the belt in contact with the cast metal to prevent excessive temperature rise of the belts. This expedient is required because the unconfined sheet of water in contact with the reverse surface of the belt is unable to take up heat at the water/belt interface sufficiently rapidly.

To improve the heat exchange it is necessary to increase the turbulence in the boundary layer at the belt/water interface and we find that the jet cooling system, most preferably employed in the apparatus of the present invention, is a particularly effective method of increasing such turbulence. In our preferred system, jets of water are directed at a large angle to the surface of the belt (such angle being very

conveniently 90°). We have found that by projecting a sufficiently large volume of water in the form of jets directed at a large angle to the surface through an array of closely spaced orifices onto the back of the belt, heat may be removed about three times more rapidly from the belt than is the case with the conventional system with the result that it is possible to avoid excessive temperature rise of the belt without the use of a thermally insulating coating on the metal side of the belt.

Since the volume of water applied is very large, means must be provided for collecting the water applied to each belt and with this object in view a casting apparatus of the present type is provided with a belt cooling system co-operating with those areas of the belts which define the casting zone, the belt cooling system comprising, for each belt, an enclosed casing which is maintained in substantially sealed relation with the belt at or outwardly of the periphery of the casting zone, the casing having belt-support portions which are maintained in sliding or rolling contact with the belt surface and which form a minor proportion of the area of the casing facing the belt, water channels lying between said belt-support portions and extending over a major proportion of the area of the casing, water-jet orifices being arranged in the floor of said water channels and being arranged to direct jets of water, drawn from a water supply, at a large angle onto the surface of the belt and drain passages to drain off water from said water channels to a water outlet. Preferably the inlet water is supplied to a first plenum chamber, from which it is directed onto the belt through orifices formed in the thickness of the metal, forming the floor of the water channels, an outlet plenum chamber being provided outwardly of the inlet plenum chamber and being connected with the water channels by large diameter drain tubes which extend through the inlet plenum chamber. The belt-supporting portions of the casing are preferably arranged so that all areas of the belt directly opposite the cast metal are in direct contact with water during a major proportion of the time they are in the casting zone. Most preferably the belt supports are formed of narrow bars of anti-friction material extending transversely of the casing, the jet orifices being arranged in one or more transverse rows between adjacent bars. The jet orifices in different rows are preferably staggered in relation to each other. The interval between jet orifices in the same lateral row preferably does not exceed 1 inch and the size of and distribution of the orifices is such that when a small pressure difference, for example 4 p.s.i., is maintained between the inlet plenum chamber and the outlet plenum chamber, water is applied to the surface of the belt at the rate of 50-150 galls/sq.in./hr.

Referring now to the accompanying drawings:—

Figure 1 is a diagrammatic side view of one form of casting apparatus,

Figure 2 is a plan view of one form of unit for supporting the belts by differential pressure and applying coolant,

Figure 3 is a plan view of the encircled portion of Figure 2, on a larger scale,

Figure 4 is a section of Figure 2, on line 4-4 showing also a belt,

Figure 5 is a section of Figure 2, on line 5-5,

Figure 6 is a part plan view of the launder,

Figure 7 is a side view of the launder in operative position,

Figure 8 is an underneath plan view of a magnetic belt support,

Figure 9 is a section on line 9-9 of Figure 8, and

Figure 10 is a section on line 10-10 of Figure 8 with the casting belt added.

The apparatus illustrated in Figures 1-7 is described and claimed in our co-pending Patent Application No. 4780/71 (Serial No. 1 387 992) out of which the present Application is divided.

The apparatus shown in Figure 1 comprises a fabricated support frame 1, on which is mounted upper and lower casting belt drive pulleys 2. A variable speed drive motor 3 drives a shaft 4 through chain 5 and sprocket 6. Drive is taken from shaft 4 to the lower casting belt drive pulley 2 via sprockets 7 and 8 and drive chain 9. Drive is taken from the lower casting belt drive pulley 2 to the upper pulley 2 by chain 11 which passes round upper and lower sprockets 12 and idlers 14, one of which is carried on a pivoted arm 14′ for tensioning chain 11. The casting belts 15 respectively pass around their drive pulleys 2 and tensioning pulleys 16, which are rotatably mounted in slides 17, guided in slide frames 18, which are pivotally connected by pivots 19 to main frame 1 and to which a predetermined casting belt tensioning force may be applied by means of pneumatic cylinders 20. The slides 17 are longitudinally movable in the frames 18 by means of adjusters 21 for the purpose of tracking the casting belts.

The upper belt 15 carries a pair of edge dams 22, which are in the form of bands of resilient heat resisting and thermally insulating material. Such edge dams are slightly compressible so as to provide a satisfactory seal in the casting zone when it is arranged to taper longitudinally, as ex-

plained above. One form of material suitable for such edge dams is in the form of a white metal or rubber core which is wrapped with a woven asbestos cloth and is supplied for use as a steam basket. The arrangement of the edge dams 22 in relation to the launder 23 is shown in Figures 6 and 7 and will be described in greater detail below. One of the units for the support and cooling of the casting belts 15 in the casting zone is illustrated in Figures 2 to 5. The belts 15 are cooled by water applied to them by means of the coolant casings 26, which will be described below. Water is drawn into the casings 26 through supply conduits 27 by means of suction pumps (not shown) connected into outlet conduits 29 so as to maintain reduced pressure on the water side of the belts.

The casing 26 is formed as a rigid, enclosed structure having a window 30 in its top surface (considering the casing as supporting the lower belt in Figure 1). The casing has a horizontal partition 31, which divides an inlet plenum chamber 32 from an outlet plenum chamber 33. Water is supplied to plenum chamber 32 through supply conduit 27 and sucked out from plenum chamber 33 through the outlet conduit 29 by the suction pump.

The plenum chamber 32 is bounded by a thick upper partition 34, the outer surface of which is slightly recessed in relation to the surface 35 of the casing surrounding the window 30. The cross-hatched portion of the surface 35 (Figure 2) is coated with an anti-friction material. Narrow belt-support bars 36 extend across the full width of the window 30 and the upper surface of these bars are ground so as to be level with the adjacent area of the surface 35. Between the points A and B the surface 35 and the upper surface of the bars 36 are ground to form a flat surface, preferably with an accuracy of the order of 2×10^{-4} inches in the longitudinal direction. The casting zone extends only between the points A and B.

Shallow water channels 37 extend between the support bars 36, the outer surface of the partition 34 and the overlying belt 15. Closely spaced jet orifices lead from the inlet plenum chamber 32 into the floor of the channels 37 and are arranged to direct jets of water substantially perpendicularly onto the surface of the belt 15. Relatively deep water-collection channels 39 in the partition 34 extend obliquely to the length of channels 37 and are connected by tubes 40 with outlet plenum chamber 33.

As will be seen, in the illustrated apparatus there are two rows of relatively staggered jet orifices 38 between each pair of belt support bars 36. The longitudinal spacing between the bars 36 is about 3/4 inch and it will be seen that the spacing between adjacent orifices 38 in the same row is similar. The diameter of the individual orifices 38 is about 3/16 inch.

When a pressure difference of the order of 4 p.s.i. is maintained between plenum chambers 32 and 33, it is found that water is applied to the back of the belt at a rate of approximately 60 galls/sq.in./hr. and, in the casting of aluminium slab, this leads to a heat transfer of about 2200 BThU/sq.in./hr. Even when the spacing of the jets is decreased and the rate of coolant water application is substantially increased, the rate of heat extraction is only increased by about 10-20%.

The apparatus is designed so that with the designed reduced pressure conditions in the rear side of the belt, there shall be substantially no sag of the belts between adjacent supports, so that the belt is not drawn out of heat exchange contact with the solidifying metal in the casting zone. In order to achieve this condition the spacing between the anti-friction support bars 36 is preferably limited to not more than 50 times, preferably 20-50 times, the thickness of the steel belt 15, which is itself of a thickness of 0.020 to 0.060 inch.

The above-described cooling system is effective to maintain the temperature difference in the belt at a value of about 30°C.

In Figure 1 the spacing between the belts 15 at the entrance to the casting zone is coarsely controlled by means of packing placed as spacers at the casing support and further finely controlled by means of adjustment screws acting on tie bars 41 so as to spring the frame 1 so that check plates 42 may be raised and lowered. The upper casing 26 is mounted in trunnion bearings 3, the axis of which is co-incident with the point B of the casing, between the check plates, so that the taper of the mold cavity between the belts 15 may be varied by angular movement of the upper casing 26 in its trunnion bearings 43 by means of a lever arm 44, which is pressed downwardly by means of a pneumatic cylinder 45 to bring a stop plate 46 into contact with an adjustable abutment 47. An upper abutment 48 is provided as a safety stop. It will be appreciated that one of the advantages of this arrangement is that if the abutment 47 is set to provide excessive taper of the mould space the solidified metal at the outgoing end of the mould space will tilt the casing 26 upyardly against the resilient loading of the cylinder 45. The abutment 47 can then be reset to provide optimum surface properties for the strip issuing from the mould space.

The launder 23 (Figure 6) is provided with a nose portion 50 which is arranged, in its operative position, to extend into the space between the belts as far as point B on the upper and lower coolant casings 26. Side dam guides 51 are secured to the side of the launder 23 and possess slight resilence so as to press the incoming side dam against the side of the launder nose portion 50 thus forming a seal at the entrance to the casting zone, so that an appropriate feeding head or pool of metal may be maintained within the launder 23 during the casting operation.

The system illustrated in Figures 2 to 5 provides satisfactory results when water is supplied to the plenum chamber 32 at a pressure of about 2 p.s.i. above atmospheric pressure, providing means are used to keep the belt in contact with the support bars 36. This could be achieved in accordance with the present invention by employing ferromagnetic support bars 36 or other magnetic or magnetisable supports, preferably of low friction material. It will be appreciated that when the casting zone is arranged in a vertical direction or is steeply inclined, the pressure of liquid metal assists in holding both the belts in contact with the supports. When the belts are employed in a horizontal position, as shown in the apparatus of Figure 1, it is preferred to operate with the inlet plenum chamber 32 at 0-4 p.s.i. below atmospheric pressure and a pressure drop of about 4 p.s.i. from the inlet plenum chamber 32 to the outlet plenum chamber 33 to draw jets of water through jet orifices 38.

In Figures 8 to 10 there is illustrated apparatus constructed in accordance with the present invention which may be substituted for that of Figures 2 to 5 for the purpose of supporting and cooling the belts. In the casting zone defined by the mould cavity the path of the belt 15 is controlled by an array 116 of magnetic pole pieces associated with an array 117 of laminated magnets. The belts 15 are cooled by water, which may contain a water-dispersible lubricant, circulated through channels 123 in the arrays of pole pieces 116, so that the backs of the belts in the casting zone are in direct contact with the cooling water. Where the coolant water contains a lubricant it is recirculated through an associated heat exchanger (not shown). Alternatively when no lubricant is employed the coolant water may be discarded after use.

The magnet array 117 may be a conventional magnetic chuck, built up from strip-like permanent magnets, separated by brass spacers.

The array 116 of pole pieces is similar constructed and comprises steel plates 121, separated by aluminium spacers 122. The projecting ends or edges of the plates 121 are tapered as shown in Figure 10 and there is defined a series of channels 123 for the passage of coolant in contact with the back of the belt 15. The plates 121 and 122 are preferably $\frac{1}{4}$ inch thick, the plates 121 tapering to 1/8 inch at their edge. The channels 123 are arranged to be about 1 inch deep.

At each side of the array 116 are provided side plates 124, which taper longitudinally, as shown in Figure 8, so that the pole piece plates 121 are arranged at a slight angle of inclination to the direction of the belt 15 to equalise the wear on the back of the belt as it moves over the pole pieces.

Coolant water, which is employed in contra-flow to the direction of belt travel, enters via a plenum chamber 125 formed in a box 126 and exits through plenum chamber 127 in a box 128.

At the water inlet end the pole pieces of array 116 have a curved external profile and the channels leading from plenum chamber 125 have a correspondingly shaped internal profile to direct the coolant water onto the inner surface of the belt. The pole pieces and waterway at the water outlet end have a similar external and internal profile, save that end spacers 129 are arranged in co-operation with plates 121 so that the belt is water-cooled over part of the curved profile at the belt (and molten metal) entry end. This ensures that the belt is fully cooled immediately prior to contact with the molten metal and avoids the belt distortion which could otherwise occur should the molten metal contact the belt prior to application of the cooling water.

In one arrangement the magnet array 117 was a commercially available Walker-Hagon Limited Model No. 20 magnetic chuck, providing an average magnetic flux density of 120 gauss at the contact of each plate 121 with the belt 15.

It has been found that with this arrangement a pressure of about 3 lbs/sq. inch may be retained behind the belt without significant leakage. With a pressure drop of 3 lbs/sq. inch it is found possible to maintain water flow along the channels 123 at a rate sufficient to maintain the temperature rise of the belt within about 80°C. over the temperature of the coolant water. To equalise the temperature across the belt and hence minimise distortion, hot is preferably supplied to those channels 123, opposite the cold, outer margins of the belt, i.e. outwardly of the edge dams 22. The temperature of the water is arranged to be similar to that of the belt in contact with metal and will generally be in the range 70-90°C. Thus those areas of the

belt which are not heated by contact with the cast strip are, instead, heated by the circulating hot water. Suitable design of the inlet and outlet plenum chambers allows the number of cold water channels to be varied to accommodate different widths of cast strip. The length of the casting zone between the belts in the illustrated construction is about 9 inches (22.5 cms) and this will allow production of strip at rates of about 30 ft./minute (9 metres/minute) at 0.1 inch thickness (9 metres/minute at 2.5 mms thickness) and 10 ft./minute at 0.3 inch thickness (3 metres/minute at 7.5 mms thickness). At these rates solidification takes place within about the first 6 inches of the casting zone.

With this arrangement it is found possible to draw the belt over the surface of the pole pieces with a pull of about 10 lbs/inch width of the array of pole pieces 116 and this may be reduced by the use of a suitable lubricant dispersed or dissolved in the coolant water. Lubricant carried over on the surface of the belt helps to lubricate it and reduce friction as it is drawn over the curved outer surfaces of the plenum chamber boxes 126 and 128 at the ends of the casting zone.

It will be appreciated that this coolant application and support system may be altered or modified in various ways. Thus the magnetic pole pieces and water channels may be arranged transversely instead of longitudinally of the belt.

In some instances, where the desired rate of heat extraction through the belt is low, the steel plates 121 are not tapered the edges of the aluminium plates 122 are level with the edges of the plates 121. Heat may then be removed by the provision of water channels within the assembly, such channels being formed by means of grooves in the side faces of the plates 121 and 122. The edge portions of the aluminium plates thus act as conductors for the transfer of heat from the belt to the coolant passing in the internally defined passages.

It will be understood that the relative inclination of upper and lower magnetic units 117 and pole piece arrays 116 may be controlled in the same manner as indicated in Figure 1 by means of air cylinder 45 and its associated stops and lever arms.

WHAT WE CLAIM IS:—

1. A method for the continuous casting of metal in strip form comprising introducing molten metal into a mould space defined between a pair of moving heat conducting ferromagnetic belts, extracting heat from said metal by cooling the reverse surfaces of said belts at said mould space, supporting said belts at said mould space by means of spaced belt supports in contact with the reverse surfaces thereof, applying a magnetic force to at least one of said belts by means of a plurality of spaced magnetic belt supports distributed over the area of the mould space to hold said belt against said supports, the magnetic force being related to the spacing between the supports and to the belt thickness to constrain said belt against buckling under thermal stresses remaining after cooling.

2. A method according to claim 1 in which the mutual inclination of said belts at the mould space is varied for variation of the longitudinal taper of the mould space.

3. A method according to claim 1 or 2 comprising applying coolant to the reverse faces of said belts by directing closely spaced jets of coolant onto said belts at a large angle to the surface thereof.

4. A method according to claim 3 in which the spacing between adjacent orifices for emission of said jets is not more than 1 inch.

5. A method according to any preceding claim in which said belts are supported in sliding relationship with stationary magnetic members.

6. A method according to any of claims 2 to 5 further including automatically increasing the spacing between said belts at the outlet end of said mould space in response to excessive thickness of solidified metal strip in said mould space at the outlet end thereof.

7. An apparatus for carrying out the method claimed in claim 1 comprising a pair of movable heat conducting ferromagnetic belts defining therebetween said mould space, said apparatus including at each side of said mould space a plurality of spaced belt supports distributed over the area of the mould space and defining the path of a belt in contact therewith, at least one of said belts being held against its supports by magnetic force applied through its said supports and means for cooling the reverse faces of said belts at said mould space, the mutual spacing between said belt supports at each side being less than 50 times the thickness of said belts.

8. An apparatus according to claim 7 further including means for varying the mutual inclination of said belts at the mould space for variation of the longitudinal taper of the mould space.

9. An apparatus according to claim 7 or claim 8 in which belt supports in contact with one of said belts form part of a unit which is pivotally mounted towards the inlet end of said mould space to permit the inclination of the path of said belt to be varied in relation to the path of the other of said belts.

10. An apparatus according to claim 9 in which said unit is resiliently loaded against a fixed stop to permit increase of spacing between said belts at the outlet end of said mould space in response to excessive thickness of solidified metal strip in said mould space at the outlet end thereoof.

11. An apparatus according to any of Claims 7 to 10 in which said belts have a thickness in the range of 0.020-0.060 inches and the spacing between the supports is 20-50 times the thickness of the belts.

12. An apparatus according to any of claims 7 to 11 in which the means for cooling the reverse faces of said belts comprises a plurality of closely spaced jet orifices, positioned to direct jets of coolant onto said belts at a large angle to the surfaces thereof.

13. An apparatus according to claim 12 in which the spacing between adjacent orifices is not more than 1 inch.

14. An apparatus according to any of claims 7 to 13 in which said belt supports are in the form of transversely arranged magnetic bars.

15. An apparatus according to any of claims 7 to 13 in which said belt supports are in the form of rotatable magnetic elements.

16. An apparatus according to any of claims 7 to 15 in which magnetic belt supports in contact with a belt are supported by a box-like unit, incorporating a first partition member spaced away from the belt path and spaced from a second partition member to define a coolant inlet plenum chamber, a plurality of apertures being formed in said first partition for delivering coolant to the reverse surface of the belt and a plurality of drain tubes connecting and extending through said first and second partitions for the passage of water to a water outlet.

17. An apparatus according to claim 16 in which said box-like unit comprises a rigid casing having a belt-contacting surface on the outside thereof, an opening in said casing lying within and surrounded by said belt-contacting surface, said belt support members being arranged within said opening and supported by said partition level with the surrounding belt-contacting surface.

18. An apparatus according to any of claims 7 to 17 further comprising a pair of flexible side dams transported with one of said belts, each of said side dams comprising an endless band of resilient, compressible thermally insulating, heat-resistant material for compensation of slight mutual inclination of said belts.

19. An apparatus according to any of claims 7 to 11 in which the belt supports for a belt comprise an array of closely spaced ferromagnetic pole pieces associated with a magnet means, said array of closely spaced pole pieces having belt-contacting surfaces defining the belt path, water passages being associated with said array of pole pieces for withdrawal of heat from said belt.

20. An apparatus according to claim 19 in which said array of pole pieces comprises a series of ferromagnetic plates separated by non-magnetic metal plates, said ferromagnetic plates projecting beyond said non-magnetic plates towards the associated belt to provide water passages defined between the reverse surface of the belt and a pair of adjacent ferromagnetic plates.

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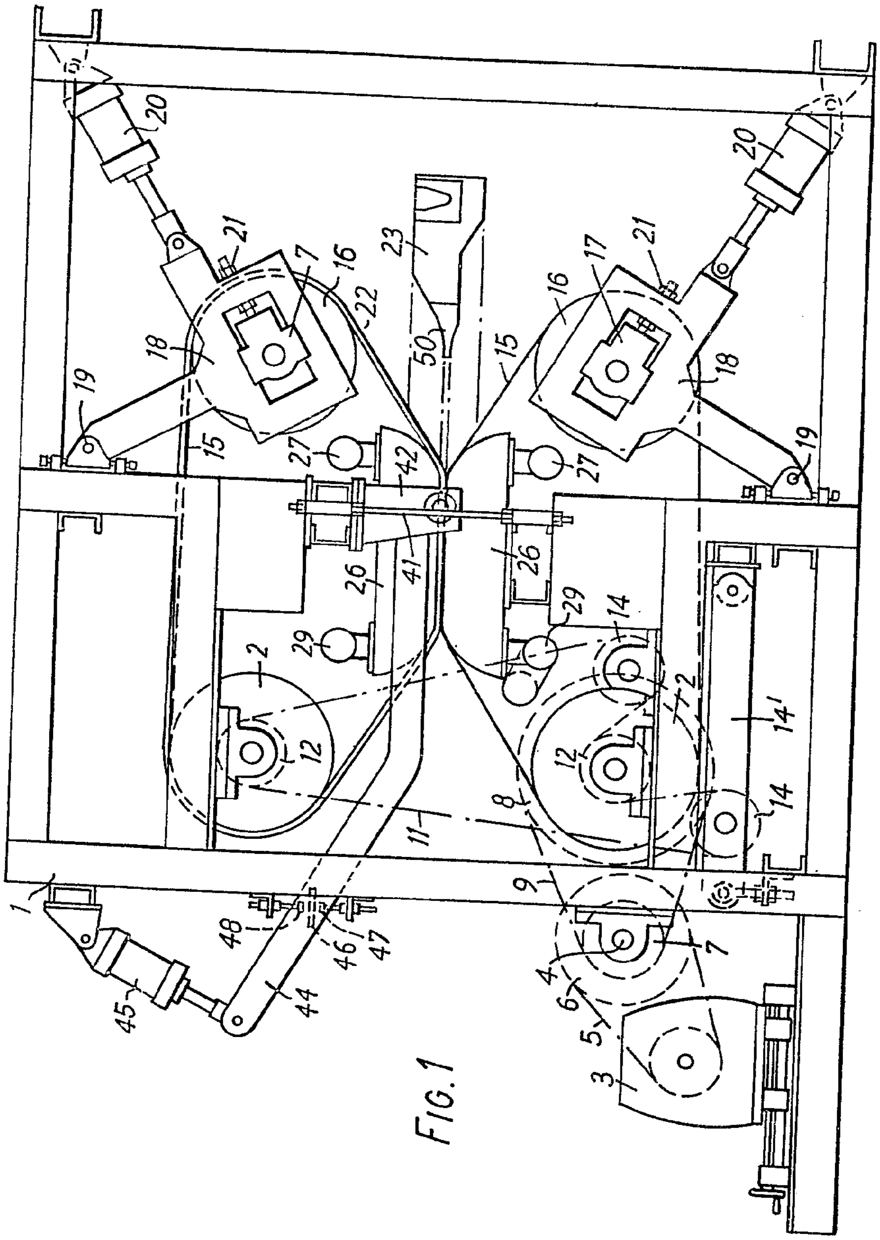


FIG. 1

FIG. 2

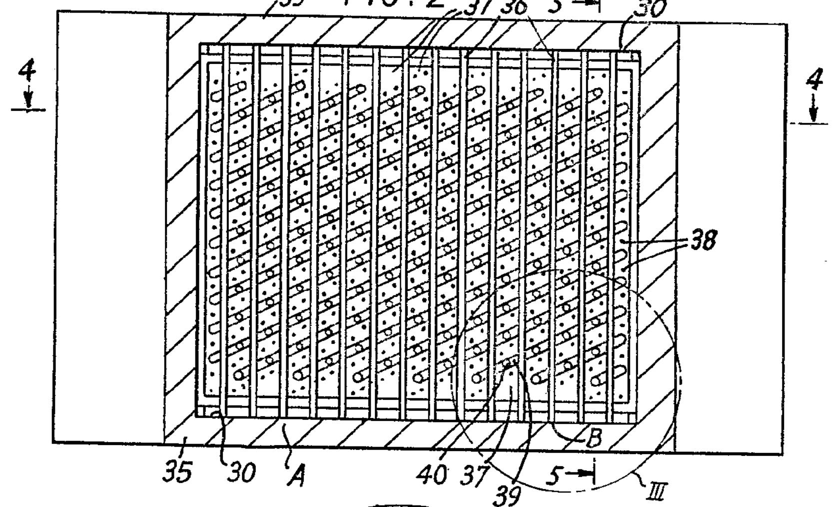


FIG. 3.

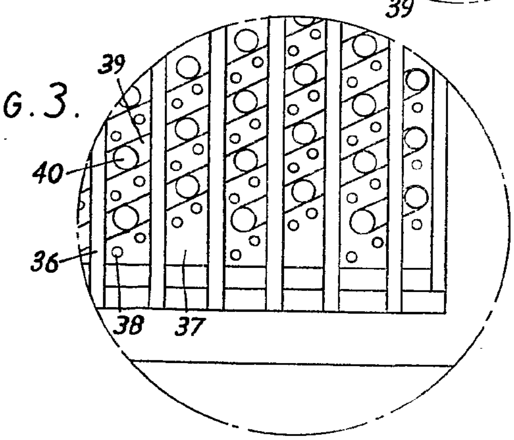
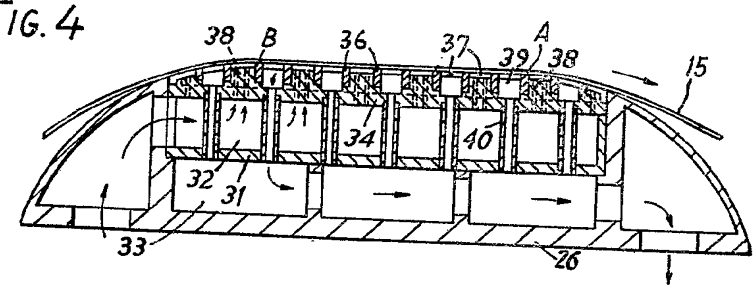


FIG. 4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B
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A
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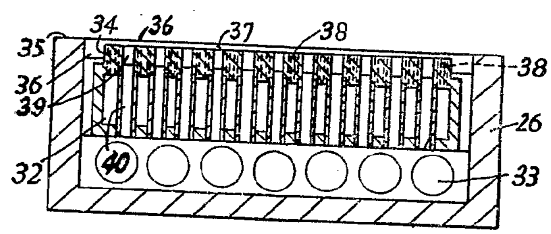
FIG. 5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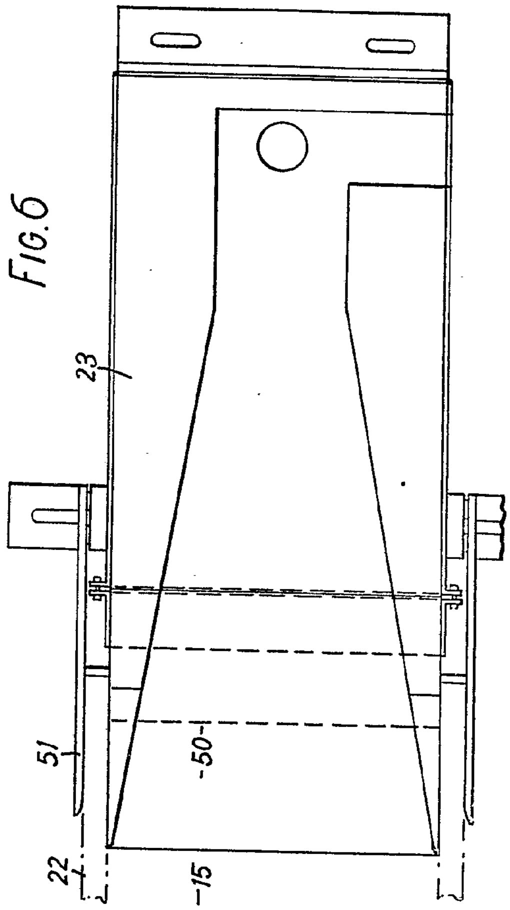

FIG.6

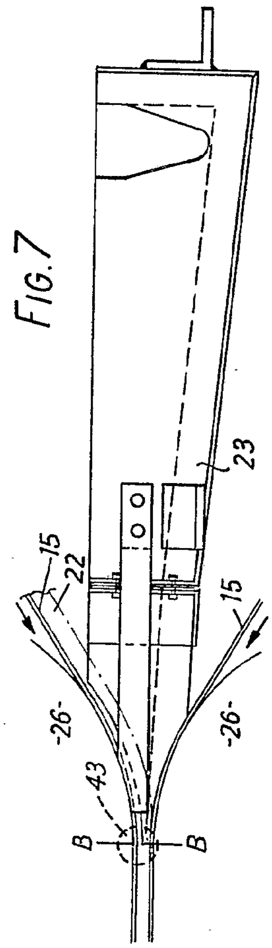

FIG.7

FIG. 8

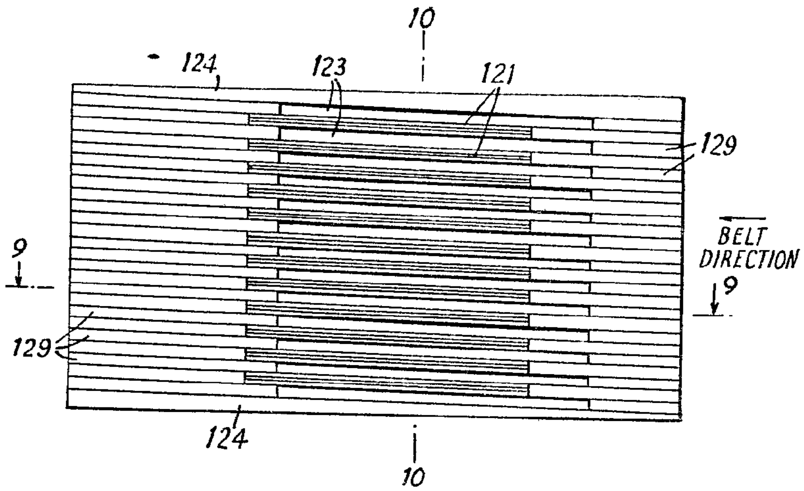

FIG. 9

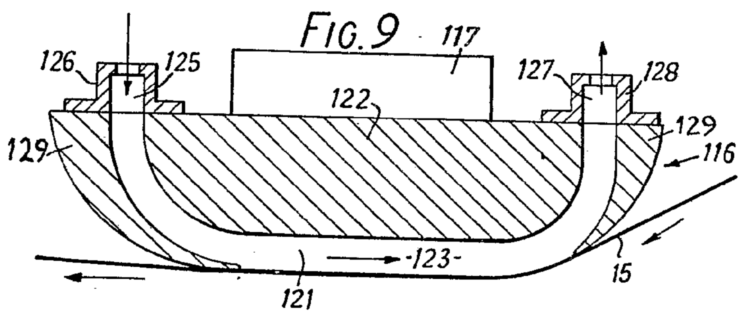

FIG. 10